

SURFACE COATINGS

## TECHNICAL FIELD

The present invention relates to protective coatings. Specifically the invention concerns hard, ductile, corrosion, wear and oxidation resistant surface coatings which can applied on substrates by thermal coating.

## BACKGROUND OF THE INVENTION

It is generally known to provide surfaces subjected to harsh conditions such as excessive wear, corrosive environment etc with protective coatings. The coatings are applied in the form of powdered materials by methods such as thermal spraying and plasma arc welding etc. Depending on the final use of the coated substrate a large variety of powdered metallic materials have been developed.

The base element of the powdered material is frequently nickel and a common alloy system used is nickel alloyed with silicon and boron. In order to make the powder melt at a lower temperature the powdered material may include phosphorous as is disclosed in the US patents 4 231 793 and 5 234 510.

A problem with these powders, especially when it is desired to apply the coating rapidly using a high energy input, is that the molten powder, when applied to the substrate, has too low viscosity which in turn results in difficulties to restrict the melt on a specific surface area of the substrate. According to the present invention it has been now found that this problem may be minimized or even eliminated by adding controlled amounts of copper or iron to the powdered material which is to be applied on the substrate.

The use of copper in connection with protective coatings intended for copper based substrates is

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disclosed in US 5 496 391. According to this patent the copper should be added in amounts above 5 % by weight and even up to 30 % by weight in order to avoid problems related to poor wettability of the copper containing substrate and poor machinability.

According to the present invention it has been found that powdered materials including less than 5 % have a beneficial effect on the viscosity of the molten powder whereas copper additions above 5 % by weight markedly deteriorates the appearance of the surface coating which is unacceptable.

An essential feature of the present invention is also the inclusion of carbide forming elements in the powdered material. The inclusion of small amounts of such elements will make the final coating more ductile which is believed to depend on a phenomenon generally referred to as grain size refinement. With higher amounts of carbide forming element it is also possible to get coatings having improved hardness.

#### Summary of the invention

In brief the present invention thus concerns a nickel based powdered metallic material comprising in addition to nickel, less than 5 % by weight of copper, less than 5.0 % by weight of iron, a carbide forming element, boron, silicon, phosphorus carbon and inevitable impurities.

#### Detailed description of the invention.

Specifically the present invention concerns a nickel based powdered metallic material comprising, in addition to nickel, 0 - 4.5 % by weight of copper, 0 - 5.0 % by weight of iron, whereby the total amount of copper and iron is at least 2.5 % by weight, 0.05 - 5.0 % by weight of a carbide forming element, 0.5 - 2.0 % by weight of boron, 1.0 - 4.0 % by weight of silicon, 0.5 - 4.0 % by

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the hardness. Comparatively high additions of carbide forming elements, such as between 1.0 -5.0 % by weight, will increase the hardness and wear resistance but this will also make the machinability of the applied surface coating more difficult. Thus the amount of carbide forming element should vary between 0.05-5.0 % by weight.

In the event that the substrate to be provided with the surface coating is cast iron, the carbides may be formed in situ, i.e. the formation of carbides occurs by picking up carbon from the substrate. Thus, when the powdered metallic material is applied to the cast iron substrate surface, the carbide forming element reacts with the carbon in the substrate resulting in the formation of carbide, by way of example chromium carbide. In this case the powdered material to be applied on the substrate includes a metal such as those listed above which have an high affinity to the carbon of the cast iron substrate. This must be taken into account when designing the metal powder due to the fact that cast iron is frequently used and comparatively inexpensive.

Furthermore, in the case that the substrate is cast iron the amount and type of carbides formed during the application process depends on the temperature provided, since the amount of carbon that is set free during the application depends on the temperature conditions on the substrate. The higher temperature, the more carbon is set free, and accordingly a larger amount of carbide is formed. It should be understood that other parameters also influencing the carbide formation are, by way of example, the time that the substrate is being heated during the application and the distance between the heating source and the substrate surface. Further, the preferred temperature depends of the carbide forming element used. By way of example, if chromium is used, the preferred temperature at the heating source, i.e. the fusing temperature is 850-910 °C. Accordingly, it is

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5 Thus, it is of great importance that the coating although  
providing the desired hardness can be machined using  
conventional equipment.

The application of the surface coating can be performed manually or be automatized, and irrespective of method chosen it is a generally known problem that there sometimes are problems when building layers of large thickness as the viscosity in the weld pool might be too low. The low viscosity results in dripping effects which makes high demands on the skill of the person performing the application. On the other hand, if the viscosity in the weld pool is too high it is difficult applying even layers.

The melting temperature of the used powdered metallic material must in addition not be too high, since the available maximum fusing temperature with conventional equipment is limited and the melting temperature of the substrate must also be taken into account. The melting temperature is also important since a reasonable melting temperature provides the possibility of speeding up the application process.

When the carbide forming element is present in the upper part of the above range a coating that is machinable but still provides sufficient hardness to withstand the harsh conditions prevailing in e.g. glass moulds.

The powder composition also includes carbon. The amount of carbon is decided by the required properties of the final coating. Thus if the substrate is cast iron carbon from this substrate may diffuse from the cast iron into the coating and the prealloyed carbon will be set lower.

The powdered metallic material is manufactured by conventional methods such as water atomization or gas atomization. The particle size is adapted to the application method being used. By way of example, if the powder is applied by powder welding the particle size is often in the range of 20-106  $\mu\text{m}$ . On the other hand, if the powder is applied by PTA, the particle size is often in the range of 45-150  $\mu\text{m}$ .

To enhance the wettability and to better control the formation of carbides the substrate is preheated before application of the powdered material. The preheating is preferably uniform throughout the thickness of the substrate and is thus suitably performed in an oven. The temperature can be varied depending on e.g. the purpose of the coating and available equipment. Generally the temperature interval is 300-800  $^{\circ}\text{C}$ . The preheating reduces the affordable application time since the melting of the applied powder on the substrate surface occurs faster. On the other hand, the affordable time can also be reduced by e.g. increasing the fusing temperature.

#### Examples

The invention is further illustrated by, but should not be limited to, the following preparations and examples.

#### EXAMPLE 1

A powdered metallic material of the composition according to table 1 below was prepared by gas atomization and applied on a cast iron substrate containing 3.2 % by weight of carbon and also on a substrate of mild steel having a carbon content of about 0.1 % by weight. The hardness HV30 of the coating on the cast iron substrate was 299, whereas the hardness of the coating on the mild steel substrate was 280. The higher hardness of the coating on the cast iron substrate results from the carbon pick up from the cast iron.

Table 1

Composition	% by weight
Cu	3.9
Fe	0.1
Cr	0.2
B	0.9
Si	2.2
P	2.1
C	0.03
Ni	Bal
Impurities	<1.0

- 5 Additionally the powdered material having the above composition could be applied at high temperature without problems because of the relatively high viscosity. The wettability to the substrates, cast iron and mild iron, was without remark. Also the appearance of the final coatings was acceptable.

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Example 2.

A powdered material having the composition according to table 2 was prepared.

15 Table 2

Composition	% by weight
Cu	1.7
Fe	1.5
Cr	4.9
B	1.2
Si	3.1
P	1.9
C	0.17
Ni	Bal.
Impurities	<1

Also this powder was prepared by gas atomisation. The hardness HV30 of the coating on the cast iron substrate



was 402, whereas the hardness of the coating on the mild steel substrate was 380. Thus also in this case an effect of the pick up of carbon from the cast iron substrate could be observed. Furthermore, as in the previous  
5 example, the powder was applied at high temperature and the viscosity was sufficiently high for applying the coating without problems. The wettability to both the substrates was quite acceptable as was the machinability of the coatings.

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